LEAD CONCENTRATION IN SOIL TREND ANALYSIS
EVALUATION OF THE EFFECT OF SAMPLING FREQUENCY ON TREND DETECTION
Herculaneum Lead Smelter Site
Herculaneum, Missouri

Tetra Tech EM Inc. (Tetra Tech) was tasked by the U.S. Environmental Protection Agency (EPA) Region 7 Enforcement/Fund Lead Removal program to conduct an evaluation of trend test results for soil lead concentrations at selected locations within Herculaneum, Missouri (City). Specifically, the Tetra Tech Superfund Technical Assessment and Response Team (START) 2 was requested to evaluate the effect of reducing sampling frequency on the detection of significant trends in lead concentration. Tetra Tech was requested to determine whether reducing the frequency of soil testing from quarterly to semi-annually would adversely affect the detection of significant monotonic trends in soil lead concentration. The assessment was conducted under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986. The project was assigned under START Contract No. 68-S7-01-41, Task Order No. 0027.

Tetra Tech focused its analysis on one data set called "Recontamination." This data set includes results from a number of residential properties. The data were collected from four different quadrants at each property, along with data for driveway areas at several properties. Lead concentrations were estimated at each location at approximately monthly intervals from the time removal activities were completed until March 2005 (sampling round 20). Due to the sequence of removal activities, not all properties underwent the same number of sampling events; the number of events ranged from 6 to 14 events per quadrant for individual properties. At many locations, some intervals within the series were omitted because of weather or access restrictions. The lead concentrations were determined by use of a portable X-ray fluorescence (XRF) instrument. Samples were collected and analyzed in accordance with a quality assurance project plan (QAPP) dated September 11, 2001.

This document presents the approach, results, and conclusions of a focused evaluation aimed at determining the effect of reducing sampling frequency on trend detection of lead concentrations over time.

Approach

To simulate the effect of reducing the frequency of soil sampling on the detection of trends in lead concentration, the most recent recontamination data set for Herculaneum was divided into three groups:

Group 1: Full data set (rounds 7 through 20)
Group 2: Reduced data set (rounds 7, 9, 11, 13, 15, 17, 19)
Group 3: Reduced data set (rounds 8, 10, 12, 14, 16, 18, 20)

Groups 2 and 3 were constructed by alternately eliminating every other sampling round from the full recontamination data set. Tests for monotonic trends were then conducted independently for each of the three data sets, and the results were compared side by side to evaluate the effect of reducing the frequency of sampling on the identification of significant trends in lead concentrations over time. Trend tests were conducted for individual quadrants for each property. The statistical methods used for conducting the trend tests are described in each of the previous quarterly reports that Tetra Tech has prepared for Region 7.

Results

Results of the side-by-side comparison of trends for the Group 1, 2, and 3 data sets are provided in Table 1. House numbers 101 and 102 were not evaluated in the trend analyses conducted for Groups 2 and 3 because the number of sampling events was reduced to less than four (that is, the minimum number required to conduct the Mann-Kendall test). House number 76 was not evaluated in the analysis for Group 2 for the same reason. Table 1 presents trend comparisons for 58 quadrants from 15 properties.

Agreement between the Group 2 and 3 test results and the results for the full data set (Group 1) was used to assess the overall effect of reducing sampling frequency on trend detection. Table 1 presents the results for 56 comparisons between Group 1 and Group 2, and 58 comparisons between Group 1 and Group 3. The last column in Table 1 scores the number of Group 2 and 3 results in agreement with the Group 1 results. Each observation of agreement (that is, each result for a single quadrant from either Group 2 or 3 in agreement with the result from Group 1) was given a score of 1. A total score of 114 (that is, 56 + 58) would indicate full agreement for all comparisons. A total of 69 observations of

agreement out of a total possible score of 114 (61 percent agreement) resulted. Full agreement (that is, both the Group 2 and 3 results agreed with the Group 1 result) resulted for 23 out of 58 quadrants. Partial agreement (that is, at least one of the Group 2 and 3 results agreed with the Group 1 result) resulted for 25 out of 58 quadrants. Ten quadrants showed no agreement between either the Group 2 or 3 results and the Group 1 results. Three cases of false positive findings occurred. A false positive finding involves a significant trend in either the Group 2 or 3 results, but not in the Group 1 results. All significant trend results were for increasing trends. No instance of a decreasing trend occurred in the full data set or the two reduced data sets..

Conclusion

The results of this evaluation show only modest agreement between the trend results reported for the full recontamination data set versus the two reduced data sets. However, absence of full agreement among the three data groupings should be interpreted with caution when trying to determine whether reducing sampling frequency will adversely affect detection of significant trends. The reasoning is that the approach used to evaluate the effect of sampling frequency on trend detection has an important limitation that introduces bias into the interpretation of results. That is, the two reduced data sets (Groups 2 and 3) are only evaluating one-half the number of sampling events evaluated in the full data set, and sample sizes in many reduced data sets are near the minimum limit for conducting statistical trend tests. If the frequency of future sampling is reduced from quarterly to semi-annually, future trend analysis will build on the full data set, so the artificial effect of reducing the number of sampling events seen in this special evaluation will not be a factor. If the true underlying trends for lead concentrations in soil are increasing consistently over time, reducing sampling frequency from quarterly to semi-annually likely will not affect results reported by the statistical tests. Therefore, we conclude that sampling frequency can be reduced without compromising EPA's ability to accurately measure overall long-term trends in lead soil concentration.

TABLE 1
RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION
COMPARISON OF TREND RESULTS USING DATA FROM ROUNDS 7-20 WITH TWO SUBSETS OF THE DATA CREATED BY DELETING EVERY OTHER SAMPLING ROUND
HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1] (miles)	House Number	Quadrant	Group 1 (Rounds 7-20)			Group 2 (Rounds 7, 9, 11, 13, 15, 17, 19)			Group 3 (Rounds 8, 10, 12, 14, 16, 18, 20)			Number of Groups in Agreement with Group 1 Results
			Number of Sampling Events[2]	Number of Samples Above Detection Limit	Trend Test Result[3]	Number of Sampling Events[2]	Number of Samples Above Detection Limit	Trend Test Result[3]	Number of Sampling Events[2]	Number of Samples Above Detection Limit	Trend Test Result[3]	
0.10	76	Q1	7	7	No Trend	No Analysis (n<4)			4	4	No Trend	1
		Q2	7	7	No Trend				4	4	No Trend	1
0.20	20	Q1	13	13	**Increasing**	6	6	No Trend	7	7	**Increasing**	1
		Q2	13	13	**Increasing**	6	6	No Trend	7	7	**Increasing**	1
		Q3	13	13	**Increasing**	6	6	**Increasing**	7	7	**Increasing**	2
		Q4	13	13	**Increasing**	6	6	No Trend	7	7	No Trend	0
	101	Q1	6	6	No Trend	No Analysis (n<4)			No Analysis (n<4)			N/A
		Q2	6	5	No Trend							
		Q3	6	6	**Increasing**							
		Q4	6	6	**Increasing**							
	102	Q1	6	6	**Increasing**	No Analysis (n<4)			No Analysis (n<4)			N/A
		Q2	6	6	No Trend							
		Q3	6	6	**Increasing**							
		Q4	6	6	No Trend							
0.25	5	Q1	13	10	**Increasing**	6	4	**Increasing**	7	6	**Increasing**	2
		Q2	13	12	**Increasing**	6	5	**Increasing**	7	7	**Increasing**	2
		Q3	13	13	**Increasing**	6	6	**Increasing**	7	7	**Increasing**	2
		Q4	13	13	**Increasing**	6	6	**Increasing**	7	7	No Trend	1
	6	Q1	13	13	No Trend	6	6	No Trend	7	7	No Trend	2
		Q2	13	13	**Increasing**	6	6	No Trend	7	7	**Increasing**	1
		Q3	13	13	No Trend	6	6	No Trend	7	7	No Trend	2
		Q4	13	13	No Trend	6	6	No Trend	7	7	No Trend	2
	22	Q1	12	12	No Trend	6	6	No Trend	6	6	No Trend	2
		Q2	12	12	**Increasing**	6	6	No Trend	6	6	**Increasing**	1
		Q3	12	12	**Increasing**	6	6	No Trend	6	6	**Increasing**	1
		Q4	12	12	**Increasing**	6	6	**Increasing**	6	6	No Trend	1
	24	Q1	10	10	No Trend	4	4	No Trend	6	6	**Increasing**	1
		Q2	10	10	**Increasing**	4	4	No Trend	6	6	**Increasing**	1
		Q3	10	10	No Trend	4	4	No Trend	6	6	No Trend	2
		Q4	10	9	**Increasing**	4	3	No Trend	6	6	**Increasing**	1

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0.40	12	Q1	14	11	**Increasing**	7	6	No Trend	7	5	No Trend	0
		Q2	14	9	**Increasing**	7	3	No Trend	7	6	**Increasing**	1
		Q3	14	12	**Increasing**	7	6	No Trend	7	6	**Increasing**	1
		Q4	14	13	**Increasing**	7	7	No Trend	7	6	**Increasing**	1
	17	Q1	13	13	**Increasing**	6	6	**Increasing**	7	7	No Trend	1
		Q2	13	13	**Increasing**	6	6	**Increasing**	7	7	No Trend	1
		Q3	13	13	**Increasing**	6	6	No Trend	7	7	No Trend	0
		Q4	13	11	**Increasing**	6	5	**Increasing**	7	6	No Trend	1
	21	Q1	9	7	No Trend	4	2	No Trend	5	5	No Trend	2
		Q2	9	9	No Trend	4	4	No Trend	5	5	No Trend	2
		Q3	9	9	**Increasing**	4	4	No Trend	5	5	No Trend	0
		Q4	9	9	**Increasing**	4	4	**Increasing**	5	5	**Increasing**	2
0.50	16	Q1	11	7	No Trend	4	2	No Trend	7	5	No Trend	2
		Q2	11	5	**Increasing**	4	2	No Trend	7	3	**Increasing**	1
		Q3	11	5	No Trend	4	1	No Trend	7	4	No Trend	2
		Q4	11	7	**Increasing**	4	2	No Trend	7	5	No Trend	0
	19	Q1	13	12	**Increasing**	6	5	**Increasing**	7	7	No Trend	1
		Q2	13	10	No Trend	6	4	No Trend	7	6	**Increasing**	1
		Q3	13	10	No Trend	6	6	No Trend	7	4	No Trend	2
		Q4	13	12	**Increasing**	6	5	No Trend	7	7	**Increasing**	1
0.54	9	Q1	13	13	**Increasing**	6	6	No Trend	7	7	No Trend	0
		Q2	13	13	**Increasing**	6	6	No Trend	7	7	No Trend	0
		Q3	13	13	**Increasing**	6	6	No Trend	7	7	No Trend	0
		Q4	13	12	**Increasing**	6	6	**Increasing**	7	6	No Trend	1
0.60	18	Q1	14	14	No Trend	7	7	No Trend	7	7	No Trend	2
		Q2	14	13	No Trend	7	7	No Trend	7	6	No Trend	2
		Q3	14	14	No Trend	7	7	No Trend	7	7	No Trend	2
		Q4	14	14	**Increasing**	7	7	No Trend	7	7	No Trend	0

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0.75	3	Q1	14	11	No Trend	7	5	No Trend	7	6	No Trend	2
		Q2	14	12	**Increasing**	7	6	No Trend	7	6	**Increasing**	1
		Q3	14	13	No Trend	7	6	No Trend	7	7	No Trend	2
		Q4	14	13	**Increasing**	7	6	No Trend	7	7	**Increasing**	1
0.80	7	Q1	14	14	No Trend	7	7	No Trend	7	7	**Increasing**	1
		Q2	14	12	**Increasing**	7	6	**Increasing**	7	6	No Trend	1
		Q3	14	11	**Increasing**	7	6	No Trend	7	5	No Trend	0
		Q4	14	10	**Increasing**	7	4	**Increasing**	7	6	**Increasing**	2

Notes:

[1] Properties are ordered as a function of increasing distance from the smelter in miles.

[2] Trend tests were not conducted for properties with fewer than four rounds of sampling.

[3] All censored (nondetect) measurements were set equal to a concentration slightly lower than the minimum detected value

n Sample size (number of sampling events)

N/A Not applicable, no trend analysis conducted for Group 2 and Group 3